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Impact of Makowal type water system on crop productivity in Shivalik foothills of India

Sher Singh[1]*, Satvinder Singh[2], S.S. Bawa[2], S.C. Sharma[2] and Amit Salaria[2]
[1]ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora - 263 601, India
[2]Punjab Agricultural University Regional Research Station for Kandi Area, Ballowal Saunkhri – 144 521, India
*Corresponding Author's E-mail: shersingh76@gmail.com

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Abstract

The availability of water through community based water harvesting structure has intensified agriculture and improved livelihood of the surveyed beneficiary households in the Shivalik foothills of India. Before the introduction of Makowal Type Water Harvesting System (before MTWHS), only 83.8% farmers in *kharif* and 79.7% during *rabi* season were growing crops but after its introduction (after MTWHS) the corresponding values improved to 100% and 97.3%, respectively, thus increasing cropping intensity from 145% to 189%. Introduction of MTWHS enabled farmers to take paddy and agro-forestry during *Kharif*, and vegetables and fodder during *Rabi* season. The increase in cultivated area due to MTWHS was to the tune of 46.1% in *Kharif* and 36.3% during *Rabi*, while increase in crop productivity ranged from 55.1% to 111.3% in *kharif* and 8.6 to 132.0% in *Rabi* season. Better availability of irrigation changed varietal spectrum in favour of hybrids and high yielding varieties and farmers started adopting improved agronomic practices targeting better input-use efficiency. The MTWHS produced positive impact on the on-farm (crops, dairy and agro-forestry) sources of income and reduced the relative dependence on off-farm activities (labour, community forest area, etc.) for earnings. This system has brought drinking water very close to hutments of rural women thus reducing their drudgery and saving time. In general, rainwater harvesting from forest watersheds has resulted in quantum jumps in crop and milk production and acted as a catalyst to tie up the economic interest of communities, along with forest protection.

Key words

Agro-forestry, Cropping pattern, Dairy farming, Diversification, Rainwater harvesting, Technology adoption

Introduction

Water is a critical input for land based production system. New initiatives and concerted efforts have been made for upgradation and development works for improving irrigation system in India. It can be realized from the fact that the area under irrigation has been increased from 22.56 million ha in 1950-51 to 88.42 million ha in 2008-09 (Anonymous, 2011). Presently the main focus is on rainwater harvesting and its subsequent management for increasing production and productivity in rainfed areas (Saini, 2012) because the rainfed agro-ecosystem in India represents 60% of the net cultivated area and supports 40% population of the country (Sharma *et al.,* 2005; Maruthi Sankar *et al.,* 2010). The Shivalik foothill region of India is sandwiched between the Himalayas and the Indo-Gangetic alluvial plains (Mittal *et al.,* 2000) and forms one of the eight most degraded ecosystems of the country (GOI, 1998). The foothill agriculture of Shivalik region of north India could not benefit from the Green and White Revolutions due to lack of assured irrigation facilities, deep ground water table, small and scattered land holdings, scarcity of arable land and undulating terrain. This resulted in increasing unemployment, drudgery, malnutrition, poor health and enlarged economic disparities and regional imbalances within the states (Grewal *et al.,* 2001). Rainfed crops usually end up with low yields and uncertainty of returns do not prompt resource poor farmers to invest on costly inputs.

Water is a major production constraint in the overall prosperity and development of the Shivaliks (Grewal, 2008). Although, the average rainfall in this *Kandi* area varies from

1000 mm to 1200 mm (about 1.5 times higher than in the central region and 2.5 times higher than in the western and south-western regions of the state), the irrigated area is far below than the rest of the state where more than 97% of the area is under assured irrigation. In comparison, only about 20% of the cultivated area in *Kandi* is under assured irrigation (Saini, 2012). Rainfall is seasonal and 80% of total average annual rainfall is received within three months of the monsoon period (late-June to mid-September) resulting in severe soil erosion with flash floods and frequent droughts and frequent crop failures due to erratic spatio-temporal distribution of rainfall (Singh *et al.,* 2002). Therefore, management of rainwater in this region is a key to environmental, economical and social sustainability (Roy, 2005). Harvesting surplus monsoon rainwater and its efficient use during the post-monsoon dry period for flood moderation and drought mitigation seems the only way to turn physical features of the land and improve the socio-economic upliftment of the people in this region (Grewal, 2008).

Rainwater harvesting acts as an important measure to conserve, develop and utilize natural resources. An efficient conservation and scientific management of harvested water is crucial for optimum utilization of water for crop production, domestic use and industrial purposes. Recognizing the sparse development of *Kandi* area of Punjab, the state government has initiated two ambitious development projects financed by the World Bank (Grewal *et al.,* 2001). Under these projects, irrigation was the major component for development of this area and construction of micro irrigation structures was one of the aspects of the irrigation component. The importance of irrigation in the development process of agriculture has been clearly brought out by micro as well as macro level studies in India (Vaidyanathan *et al.,* 1994). This has given a new direction in management of natural resources for mutual benefit of the people as well as fragile hilly eco-system.

These Makowal Type Water Harvesting Systems constructed by the Government were entrusted to local farmers by constituting Water Users Committees of farmers of the village for independent use and distribution of water; collection of water charges and repair and maintenance of these structures (Kaur *et al.,* 2010). The specific objective of this study was to assess the impact of community based Makowal Type Water Harvesting System on cropping system, land use pattern, input use, cultural practices, productivity level and sources of income of beneficiary households in the Shivalik foothills of northern India.

Materials and Methods

Study area : The study domain is the two sites located in the sub-mountainous area comprising of Shivalik foothills in the state of Punjab, known as the *Kandi* tract and covered under the community based Makowal Type Water Harvesting System (MTWHS). MTWHS are modernized forms of the ancestral *Kuhls* in which naturally seeping water from the foothills is channelized through underground pipelines and supplied for irrigation (Kaur *et al.,* 2010). The study area represents rainfed agro-ecosystem, characterized by undulating topography and erosion prone soils with inherent poor fertility. The underground water is deep and difficult to lift for irrigation and domestic uses. The region witnesses sub-humid climate with hot and dry summer and extremely cold winter. The average annual rainfall of the study domain is around 1100 mm, of which nearly 80% is received during a short time span of three months (end-June to mid September) (Sharma *et al.,* 2010). Rainfall in this region generally remains uneven and erratic, both in occurrence and distribution throughout the year.

Moisture stress at maturity stage in *Kharif* crops and establishment of *Rabi* crops is a common feature that seriously affects the prospects of successful and sustainable rainfed agriculture. Small land holdings, lack of irrigation facilities, low level of input use, heavy biotic pressure on natural forests, inadequate vegetative cover, heavy soil erosion, landslides, declining soil fertility and frequent crop failures resulting in scarcity of food, fodder and fuel are the characteristics of this region (Grewal 1995). Rainfed maize (*Zea mays*)-wheat (*Triticum aestivum*) is the dominating cropping system of the region where maize is grown from June/July to October (*Kharif* season) while wheat during October/November to April (*rabi* season).

Data collection and analysis : The study target mainly interprets changes in cropping pattern, land use pattern, input use, cultural practices, productivity level and sources of income due to introduction of MTWHS (after MTWHS) and is based totally on primary data. A total of 74 beneficiary households (26 from site-**I** and 48 from site-**II**) in the area benefited by MTWHS were randomly selected and intensively surveyed, comprising farmers' views on the above mentioned aspects during 2009-10. At the same time, sample beneficiary households were also interviewed on these aspects being adopted by them before introducing MTWHS (before MTWHS). Each beneficiary household was visited twice to collect information independently for *Kharif* and *Rabi* seasons. The data were collected with the help of specifically designed and pre-tested questionnaires.

The data on different aspects were analyzed across two categories i.e., 'before MTWHS' and 'after MTWHS' for comparison and impact assessment, if any. For subsequent analysis and reporting, the surveyed beneficiary households were classified into three irrigation categories based on the frequency of getting turn for irrigation water through MTWHS. Amongst the 74 farmers in the survey, 22 were classified as receiving low (1 irrigation month^{-1}), 42 as intermediate (1-2 irrigations month^{-1}) and 10 as high (>3 irrigations month^{-1}) frequency of irrigation. For the beneficiary household level analysis, tables therefore typically included average of each category as well as the overall sample, indicating statistically significant differences between irrigation categories where relevant. Data were analyzed using SPSS (version 16.0) statistical software (SPSS, 2007) and significance (p = 0.10) levels were calculated using appropriate statistical tests (e.g. Chi^2, ANOVA with post-hoc test). Unless otherwise stated, the sample size was 74 for both *Kharif* as well as *Rabi* season.

Results and Discussion

The survey results showed that the overall average land holding size of 74 surveyed beneficiary households was 0.76 ha and most of the farmers (79.7%) were marginal with a land holding size of <1.0 ha (Table 1). The average functional water charges for MTWHS were INR 9.5 hr^{-1} and all the farmers expressed their level of satisfaction with the Water Users Committee relative to costing charges being paid towards repair and maintenance costs (Kaur *et al.,* 2010). Since MTWHS is based on the working principle of gravity flow, therefore, no energy costs are involved and the minimal recurring costs are generally met out from collective generated outlay. Approximately two-third farmers reported that sufficient water was available through MTWHS during the peak periods of crop growth. On an average, about 87.5% of the representative farmers reported that the frequency of getting their turn for irrigation water through MTWHS was up to 3 days month^{-1} while 13.5% of them reported >3 days month^{-1}.

Overall, all the farmers were satisfied with their active participation and committed efforts for sustained performance of MTWHS at both the sites. Grewal (2000) also reported that water can be made available for irrigation to the local community through implementation of base flow water harvesting projects and its success depends on the commitment of the community to protect the donor forest catchment of the project. On an average, farmers got turn for irrigation water through MTWHS @ 2.4 days month^{-1}. The perennial flow harvesting ensured round the clock water supply to meet varied demands of the community.

Before the construction of MTWHS, about 16.2% farmers in *Kharif* and 20.3% during *Rabi* season did not grow even a single crop but a major shift in crop growing pattern was observed with introduction of new crops in the command area, depending on water requirement and availability in different seasons after introduction of MTWHS. The availability of supplemental irrigation from harvested rainwater enabled the farmers to step up cropping intensity from 145 to 189% by virtue of introducing 2 to 4 new crops in *kharif* season and 3 to 5 crops in *rabi* season, leading to a diversified cropping pattern (Table 2). Similar reports on increased cropped area (Agnihotri *et al.*, 2008) and cropping intensity (Mittal and Aggarwal, 2002; Arya *et al.*,, 2011) with the introduction of WHS have been reported earlier.

Data Analysis through multiple response variable depicted in Fig. 1 shows that after MTWHS, the percentage of farmers keeping their fields fallow reduced drastically from 24.3 to nil during *Kharif* and 28.4 to 6.8 during *Rabi* season. Similarly, the interest of farmers in growing crops like *Taramira* (*Eruca sativa*), Indian mustard (*Brassica juncea*), intercrops and pulses reduced after MTWHS. However, the percentage of farmers growing pearl millet (*Pennisetum glaucum*) as fodder, maize and wheat increased from 54.1 to 63.5, 71.6 to 85.1 and 75.7 to 94.6%, respectively. In addition, farmers also showed their interest in cultivating crops like paddy (*Oryza sativa*) and introduced agro-forestry (*Populas deltoids* and *Melia azedrack*) during *Kharif*, and vegetables and fodder crops like Egyptian clover (*Trifolium alexandrinum*) during *Rabi* season. Development of water resources for assured supplemental irrigation was the major governing factor for conversion of fallow land into cultivated land, which not only diversified the system but also provided handsome remuneration to the farmers. Grewal (2000) and Kurian *et al.* (2004) have also signified the importance of rainwater harvesting

Table 1 : Land holding characteristics and response of beneficiary farmers about Makowal Type Water Harvesting System (MTWHS) across two sites

Particulars	Site-I (n=26)	Site-II (n=48)	Average (n=74)
Average size of land holding (ha)	0.59	0.85	0.76 (±0.79)[a]
Size of land holding (% reporting)			
<1.0 ha	92.3	72.9	79.7
1.0-2.0 ha	3.8	18.8	13.5
>2.0 ha	3.8	8.3	6.8
Water charges of MTWHS (INR hr^{-1})	10.0	9.27	9.5 (±1.1)
Is sufficient water available during peak period? (% reporting)			
-Yes	100.0	47.9	66.2
-No	-	52.1	33.8
Frequency of getting turn for irrigation water (% reporting)			
1 day month^{-1}	-	45.8	29.7
2-3 days month^{-1}	88.5	39.6	56.8
>3 days month^{-1}	11.5	14.6	13.5
After how many days in a month do the farmers get turn for irrigation water? (days month^{-1})	3.0	2.2	2.4 (±1.1)

MTWHS=Makowal Type Water Harvesting System; *Note*: Column sums may not add up to 100% due to rounding; [a] Value in parentheses: ± SD towards increasing crop diversification while reducing the risk of crop failures consequently, paving the way to improved productivity, sustainability and economic viability of small and marginal farmers in the Shivalik foothills. Gill *et al.* (2009) also emphasized the role of diversification through different enterprises as a mean of income generation.

Table 2 : Number of crops grown by farmers across the crop season

Particulars	Before MTWHS	After MTWHS
Kharif season (% reporting)		
- No crop	16.2	-
- 1 crop	41.9	39.2
- 2 crops	41.9	33.8
- 3 crops	-	21.6
- 4 crops	-	5.4
Std. Dev. (±)	0.72	0.91
Rabi season (% reporting)		
- No crop	20.3	2.7
- 1 crop	25.7	59.5
- 2 crops	28.4	27.0
- 3 crops	25.7	4.1
- 4 crops	-	5.4
- 5 crops	-	1.4
Std. Dev. (±)	1.08	0.94
Cropping intensity (%)	145	189

MTWHS=Makowal Type Water Harvesting System; *Note*: Significance levels are from Chi^2 (% data). Column sums may not add up to 100% due to rounding

The use of harvested rainwater through introduction of MTWHS drastically changed the cropping pattern and yield scenario in the study domain. Before inception, whole of the cultivatable area (100%) of the surveyed beneficiary households was under rainfed farming in both the seasons but after construction of MTWHS majority of the area (81.6 % in *Kharif* and 91.5% in *Rabi*) became irrigated (Table 3). The base flow from the forest watersheds was more after rains upto March and reduced thereafter during May-June and this trend synchronized with water requirement of crops. When discharge was low in summer, there was no crop in field and MTWHS was therefore compatible with agricultural requirement of the domain area. Maize and paddy in *Kharif*, and wheat, vegetables and fodder in *Rabi* season were more or less irrigated. Other crops like pearl millet (fodder), *Taramira* and Indian mustard got comparatively less attention because farmers preferred to irrigate food grain, fodder and high value crops.

With the introduction of MTWHS, majority (90.1 % in *kharif* and 65.1% in *rabi*) of the fallow land (irrespective of the cropping season) came under cultivation with the availability of irrigation facilities. Before MTWHS, cropped area was only 66.1% in *Kharif* and 64.2% during *Rabi* season which increased to the tune of 96.6% and 87.5%, respectively after MTWHS. The change (%) in cropped area due to MTWHS in terms of increase was 46.1 during *Kharif* and 36.3 during *Rabi* season. Agnihotri *et al.* (2008) reported that in the Shivalik foothills of Himachal Pradesh, 64% of the area taken earlier under rainfed farming came under irrigation with the introduction of water harvesting

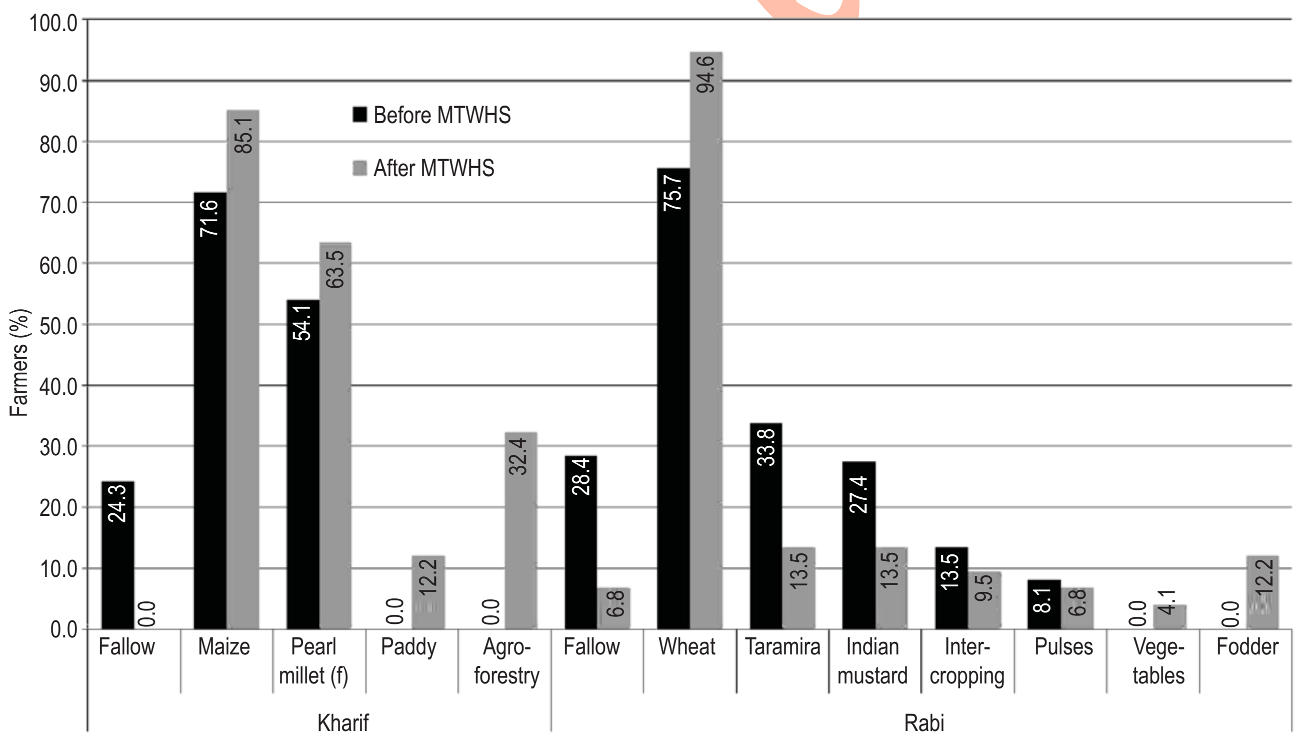

Fig. 1 : Status of crops grown by farmers across the crop seasons

structures. Increase in cropped area (27.4% in *Kharif* and 46.8% in *Rabi* season) due to the use of harvested rainwater was also reported.

A shift in area under different crops was also observed due to introduction of water harvesting structure (Table 4). During *Kharif*, the maximum increase in area was observed in pearl millet (fodder) (46.8%) followed by maize (14.9%). Paddy crop, which otherwise was not in existence, later got introduced in 12.0% area. Cultivation of fallow land, due to availability of water was the major factor responsible for this change. During *Rabi* season, such an increasing trend for cultivable area was observed only in wheat crop (79.9%), with additional introduction of vegetable and fodder crops associating it with reduction in area under *Taramira*, Indian mustard and pulses and cultivation of fallow land. Kaur *et al.* (2010) and Rana and Gupta (2010) has also reported changes in land-use pattern in this region with the construction of micro irrigation structures.

Since rainfall in this area mostly recedes by mid or end September, *Rabi* crops are generally sown on residual soil moisture, resulting in improper germination and poor crop yields. Before MTWHS, crop productivity of the beneficiary households was very low (Table 4) enabling themselves to purchase food grains from outside market to cater the household requirements for themselves and fodder for their livestock. But introduction of MTWHS strengthened irrigation facilities for applying pre-sowing irrigation to *Rabi* crops and most of the farmers preferred pre-sowing irrigation ensuring better crop stand and higher crop productivity. This not only served the purpose of subsistence farming but they had surplus to sell. The perennial flow of MTWHS provided livelihood security to the farming community against

Table 3 : Change in irrigated and cropped area across the crop seasons

Particulars	Area (ha)			Area (ha)		
	Rained	Irrigated	Total	Fallow	Cropped	Total
Kharif						
- Before MTWHS	56.50 (100.0)	-	56.50	19.13 (33.9)	37.37 (66.1)	56.50
- After MTWHS	10.40 (18.4)	46.10 (81.6)[a]	56.50	1.90 (3.4)	54.60 (96.6)	56.50
- Change (%)	-81.6	-	-	-90.1	+46.1	-
Rabi						
- Before MTWHS	56.50 (100.0)	-	56.50	20.22 (35.8)	36.27 (64.2)	56.50
- After MTWHS	4.80 (8.5)	51.70 (91.5)[a]	56.50	7.05 (12.5)	49.45 (87.5)	56.50
- Change (%)	-91.5	-	-	-65.1	+36.3	-

MTWHS=Makowal Type Water Harvesting System; The values in parenthesis is percentage; [a] also includes area irrigated through tubewell to the tune of 5.0% and 6.4% during *Kharif* and *Rabi* season, respectively

Table 4 : Shift in area under different crops and their productivity across the crop seasons

Season/crops	Area under crops (ha)			Grain or seed yield (t ha^{-1})		
	Before MTWHS	After MTWHS	Change (%)	Before MTWHS	After MTWHS	% increase over before MTWHS
Kharif						
- Fallow	19.13 (33.9)	1.90 (3.4)	-90.1	-	-	-
- Maize	22.17 (39.2)	25.48 (45.1)	14.9	1.50	3.17	111.3
-Pearl millet (f)*	15.20 (26.9)	22.32 (39.5)	46.8	26.31*	40.81*	55.1
- Paddy	-	6.80 (12.0)	-	-	5.14	-
- Total	56.50	56.50	-	-	-	-
Rabi						
- Fallow	20.22 (35.8)	7.05 (12.5)	-65.1	-	-	-
- Wheat	22.90 (40.5)	41.20 (72.9)	79.9	1.53	3.55	132.0
- *Taramira*	6.20 (11.0)	2.68 (4.7)	-56.8	0.63	0.82	30.2
- Indian mustard	4.88 (8.6)	2.32 (4.1)	-52.5	0.70	0.76	8.6
- Pulses	2.30 (4.1)	0.75 (1.3)	-67.4	0.75	0.85	13.3
- Vegetables	-	0.90 (1.6)	-	-	17.92[a]	-
- Fodder	-	1.60 (2.8)	-	-	34.72[b]	-
- Total	56.50	56.50	-	-	-	-

MTWHS=Makowal Type Water Harvesting System; Values in parenthesis are percentage; [a] Green vegetable yield; [b] Green fodder yield; Column sums may not add up to 100% due to rounding frequent droughts in the region by providing water facilities for life saving irrigation at critical growth stages of crops. Application of supplement irrigation, especially in *Rabi* crops, proved very beneficial since rainfall remains low and becomes a major yield limiting factor. In addition, the changed varietal spectrum and increased use of inputs also resulted in enhanced productivity of crops (Anonymous, 2012). Overall, introduction of MTWHS has a positive impact on the productivity of all crops. Increase in productivity of *Kharif* crops ranged from 55.1% to 111.3% while in *Rabi* crops it ranged from 8.6% to 132.0% (Table 4). The maximum increase in productivity was observed in maize (111.3%) during *Kharif* and in wheat (132.0%) during *Rabi* season. Roy (2005) and Agnihotri *et al.* (2008) have also reported increased productivity of maize and wheat due to water harvesting structures. Grewal *et al.* (1995) and Grewal *et al.* (2001) have observed almost three times improvement in crop yields in the region due to supplementary irrigations through water harvesting structures with compared as rainfed conditions. High frequency of irrigation ensured better availability of water at the critical stages of crops resulting in increased productivity (Sur *et al.,* 2001).

Poor resource base of the farmers entrusted themselves to look for local crop varieties with little implications on application of quality fertilizers, insecticides and pesticides (Table 5). The assured irrigation facilities through MTWHS changed the varietal spectrum in favour of hybrids/composites in maize (61.9%) and high yielding varieties in wheat crop (100%). Significant change in farmers' attitude and beliefs towards using the recommended seed rate was noticed after the inception of MTWHS. The percentage of farmers using recommended seed rate increased from 49.1% to 74.6% in maize and from 75 to 98.6% in wheat (Table 6). However, the seed rate used by farmers decreased from 22.5 to 21.3 kg ha^{-1} in maize and 104.7 to 100.2 kg ha^{-1} in wheat. Since the seed of hybrids/composites and high yielding varieties is costlier than the local varieties and is generally available in packings of recommended quantity, farmers used it efficiently.

Availability of water and adoption of input responsive cultivars after MTWHS led to increased use of nitrogen and phosphorus in both the crops. Increased dose of N and P dose was to the tune of 19.6% and 78.1%, respectively in maize. The corresponding values for wheat were 31.1% and 133.7%. Grewal *et al.* (2001) also reported improved use of N and P for higher crop yields in this region due to integrated watershed management. Before introducing MTWHS, only 5.7% farmers in maize and 7.1% in wheat crop were giving due attention to need based plant

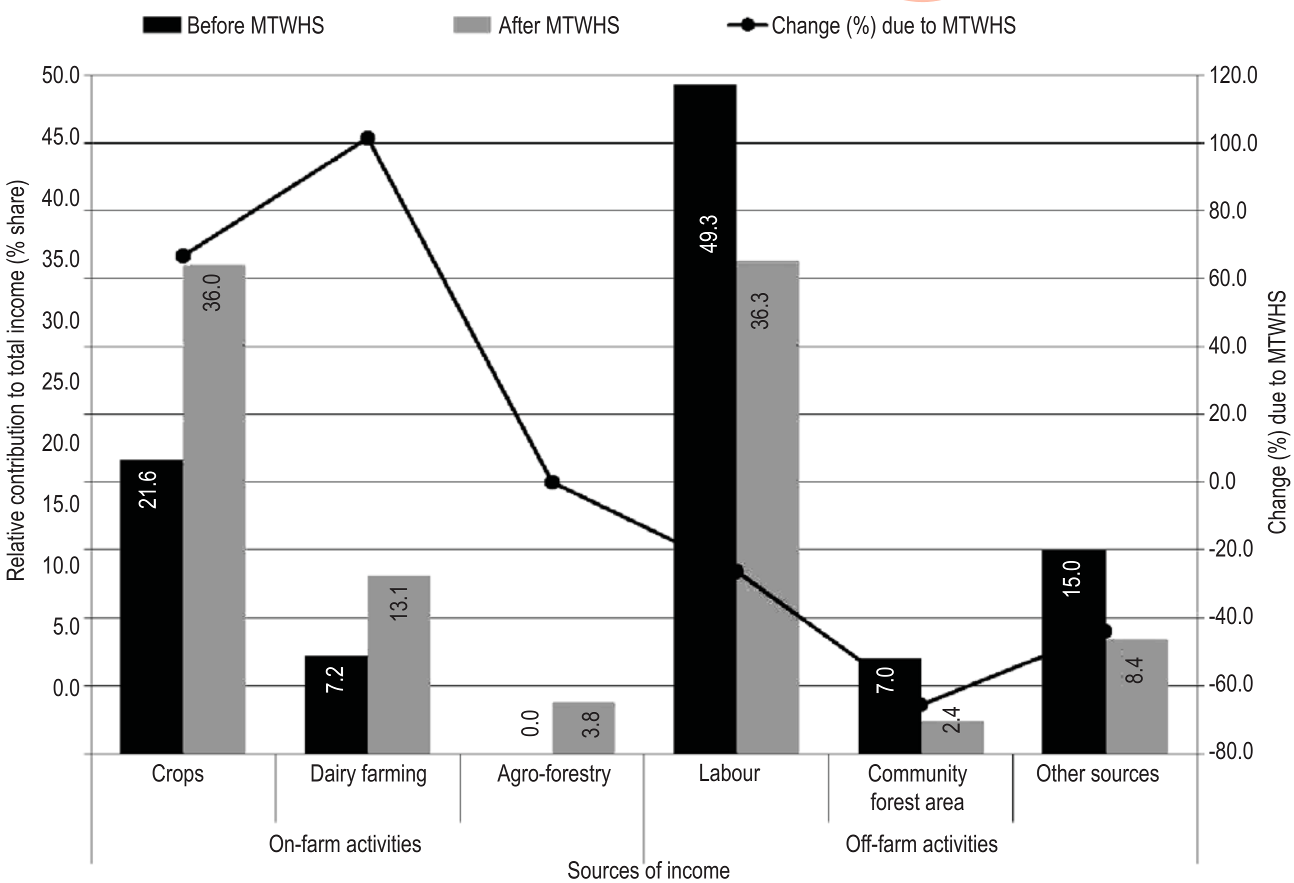

Fig. 2 : Relative contribution of different activities to total income and change (%) in income

Table 5 : Change in varietal spectrum (% reporting) in maize and wheat crops

Maize varieties/hybrids/ composites	Before MTWHS (n=53)	After MTWHS (n=63)	Wheat varieties	Before MTWHS (n=56)	After MTWHS (n=70)
Local variety	100.0	38.1	Local variety	85.7	-
Kanchan (hybrid)	-	46.0	PBW 175	14.3	17.1
Parkash (hybrid)	-	11.1	PBW 343	-	77.1
JH 3459 (hybrid)	-	1.6	PBW 502	-	4.3
Megha (Composite)	-	3.2	PBW 550	-	1.4
Total	100	100	Total	100	100
Std. Dev. (±)	-	1.87	Std. Dev. (±)	0.35	0.62

MTWHS=Makowal Type Water Harvesting System

Table 6 : Input use pattern in maize and wheat

Inputs	Maize		Wheat	
	Before MTWHS (n=53)	After MTWHS (n=63)	Before MTWHS (n=56)	After MTWHS (n=70)
Use of seed rate (% reporting)				
- Recommended[a]	49.1	74.6	75.0	98.6
- Higher than recommended	50.9	25.4	25.0	1.4
Seed rate (kg ha^{-1})	22.5	21.3	104.7	100.2
Nitrogen (kg ha^{-1})	57.6	68.9	57.5	75.4
Phosphorus (kg ha^{-1})	25.1	44.7	20.5	47.9
Use of pesticides (% reporting)				
- Yes	5.7	33.3	7.1	32.9
- No	94.3	66.7	92.9	67.1

MTWHS=Makowal Type Water Harvesting System; [a]Recommended seed rate for maize and wheat is 20 and 100 kg ha^{-1}, respectively

protection measures (weedicides, insecticide or both) but after MTWHS, use of pesticides increased and about one-third of the farmers started using pesticides in both the crops.

Agro-forestry became a new fagland source of income generation after the introduction of MTWHS. After MTWHS, impact analysis for shift in the present contribution of different farm enterprises was done and the results revealed that on-farm resources created a positive impact (14.4%, 5.9%, 3.8% improvement due to crops, dairy farming and agro-forestry) while off-farm resources created a negative impact (13%, 6.6% and 6.6% reduction due to fuel wood from the community forest area, labour and others) sources on farm income (Fig. 2). Availability of harvested water increased the number (Table 2), area and productivity (Table 4) of crops which amplified relative contribution of crops to the total income of farmers. Similarly, increase in area under pearl millet (fodder) as well as the inclusion of fodder crops in *Rabi* season further strengthened farmers' interest in dairy farming, thus assuring supply of fodder throughout the year. Enlarged engagement of farmers on their own farm round the year has led to huge reduction in drudgery and contribution of off-farm activities.

Number of irrigations received by beneficiary households increased significantly with increase in frequency of irrigation through MTWHS and the average number of irrigations received was 2.4 month^{-1} (Table 7). The increase in frequency of irrigation has a positive impact on the number of crops grown by the farmers and it reflected in terms of enhanced cropping intensity. Assured availability of harvested water make it possible for the farmers to sow more crops on larger farm land which otherwise remained fallow. In general, average number of crops grown during the *Kharif* season (1.9) was comparatively higher than in the *Rabi* season (1.6). Significant increase in the productivity potential of all the major crops (maize, paddy and wheat) was noticed with increase in number of irrigations. The frequency of irrigation also has a significant effect on relative contribution of on-farm and off-farm sources of total farm income. With increase in frequency of irrigation, the relative contribution to total income from on-farm sources (crops, dairy and agro-forestry) increased and the dependence on off-farm (labour, community forest area and other sources) sources of income reduced. The potential of water harvesting as a poverty reduction strategy through economic returns, has also been reported by Smith *et al.* (2011).

Due to migration of male members, the women of the region get burdened with large number of additional farm activities in addition to the usual child care and household management. A major part of their daily routine time is exhausted in collection of fuel wood and fodder from the community forest

Table 7 : Impact of frequency of irrigations with MTWHS on the number of irrigations/month, number of crops, cropping intensity, productivity and sources of income

Particulars	Frequency of getting irrigation water through MTWHS			Average	Significance
	1 day $month^{-1}$	2-3 days $month^{-1}$	>3 days $month^{-1}$		
No. of irrigations/month with MTWHS	1.0 a	2.8 b	3.9 c	2.4 (±1.1)	<0.001
Number of crops grown during *Kharif*	1.7 a	1.9 a	2.5 b	1.9 (±0.9)	0.06
Number of crops grown during *Rabi*	1.4	1.6	1.9	1.6 (±0.9)	NS
Cropping intensity (%)	184	190	197	189 (±28.1)	NS
Maize yield (t ha^{-1})[a]	3.00 a	3.09 a	3.88 b	3.17 (±0.79)	0.01
Paddy yield (t ha^{-1})[ab]	-	4.78	6.38	5.14 (±0.79)	0.03
Wheat yield (t ha^{-1})[a]	3.37 a	3.56 ab	3.89 b	3.55 (±0.60)	0.08
Relative contribution (%) of on-farm sources to total income after MTWHS	46.5 a	51.7 a	71.0 b	52.8 (±19.8)	0.01
Relative contribution (%) of off-farm sources to total income after MTWHS	53.5 b	48.3 b	29.0 a	47.2 (±19.8)	0.01

MTWHS = Makowal Type Water Harvesting System; [a]With respective to only those farmers who sow a particular crop; Value in parentheses: ± *s.d.*
[b] Post hoc tests were not performed for paddy yield because there were fewer than three groups; *Note*: Significance levels are from one-way ANOVA. Data followed by different lower-case letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison).

area and also, in arrangement of water in areas where water scarcity is very acute. The base flow harvesting projects have brought water very close to their hutments and drudgery of rural women has reduced. They now use their spare time in other useful activities and spend more time on their own farms in fodder collection, chaffing and feeding livestock rather than going into the forest for a headload of fuel wood and fodder (Grewal, 2000).

Availability of harvested water considerably provided livelihood security to the people. The assured fodder availability has turned up dairy farming into a business enterprise and the regular cash flow through the sale of milk has improved women empowerment. The in hand cash availability has improved the farmers resource base and risk bearing capacity to spend more on farm inputs, leading to improved productivity. Stall feeding has reduced load on the community forest area and increased the availability of manures. Agro-forestry has proved a source of extra income and has fulfilled the requirement of fuel wood and reduced load on the community forest area, thus protecting the environment and saving time of women being consumed in its collection. Grewal *et al.* (2001) has also reported that water resource development changed the entire routine of farm families in favour of profitable agri-business.

Makowal Type Water Harvesting System (MTWHS) has ensured round the clock water supply to meet varied demands of the community (Singh *et al*., 2014). As an outcome of MTWHS, the agricultural production has increased and in place of rainfed farming, farmers have started getting assured crops with irrigation. With the availability of irrigation, farmers have initiated use of improved agronomic practices. A huge difference in productivity of crops before and after MTWHS show that water harvesting structures have great bearing on the income of beneficiary households, particularly small and marginal farmers who constitute a major portion of the population in the Shivalik foothills. Construction of micro irrigation structures has helped in saving land from soil erosion and sedimentation. Human resources have been saved and used for other productive purposes. This type of water harvesting structure has ushered a new chapter in watershed development with a sharp focus on resource conservation and poverty alleviation.

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